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DYNAMICS OF ROTATING AND OSCILLATING DROPS

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INTRODUCTION

This experiment was the first investigation into the dynamics of rotation and oscillation of a freely suspended liquid drop under the influence of surface tension and positioned inside an experimental apparatus by acoustic forces in the low acceleration environment of Spacelab 3. After a drop was observed to be spherical and stably located at the center of the chamber it was set into rotation or oscillation by acoustic torque or modulated radiation pressure force.

EQUILIBRIUM SHAPES OF A ROTATING DROP

When a liquid drop spins slowly, it assumes an axisymmetric shape with respect to the rotation axis. As the rotation rate increases, the axisymmetric shape loses its stability and develops into non-axisymmetric shapes having 2, 3, or 4 lobes. These transitions, or bifurcation points, have been predicted by analytical and numerical techniques [1,2]. Experimental evidence of these equilibrium shapes and bifurcation points has been observed in the laboratory using immiscible liquids in neutral buoyancy tanks [3]. However, these results cannot be correlated with theoretical predictions because of the viscous stresses and inertial drag exerted by the host fluid.

Mixtures of glycerin and water were used to form drops with various viscosities for this experiment. Typically, several spin-up and spin-down sequences were performed for a given experimental run with the drop shapes recorded on cinefilm. Figure 1 shows experimental data for a 100 cSt liquid drop, 3 cc in volume, with a rotational acceleration of about 0.01 rev/sec^2. The data yields very good agreement with theoretical predictions in the axisymmetric region, but an obvious difference occurs in the location of the bifurcation point: experimentally ω(II) was 0.47, and theory gives 0.56. This difference suggests that the axisymmetric shapes are less stable than predicted by the theory in the region near the bifurcation point [4]. In Figure 1, the rotation rate has been normalized to the frequency of the first mode of shape oscillations, and one-half of the maximum equatorial discussion of the deformed drop (RMAX) has been divided by the radius of the initially spherical drop (RO).

SHAPE OSCILLATION OF A DROP

The oscillation experiment on this flight was curtailed due to lack of operation time and sub-nominal performance of the instrument. Nevertheless, the available data suggest to a hard non-linearity in the resonance frequencies for shape oscillations as the amplitude grows larger (shown in Figure 2). This is contrary to ground-based experiments which suggest a soft non-linearity [5]. The results of Figure 2 have been obtained by observing the free decay of an initially deformed drop. The resulting shape oscillations are of the oblate-prolate type.

CONCLUSION

In conclusion, the availability of low gravity environment of the Spacelab flight has provided the first opportunity to perform drop dynamics experiments for the rigorous testing of existing theories.

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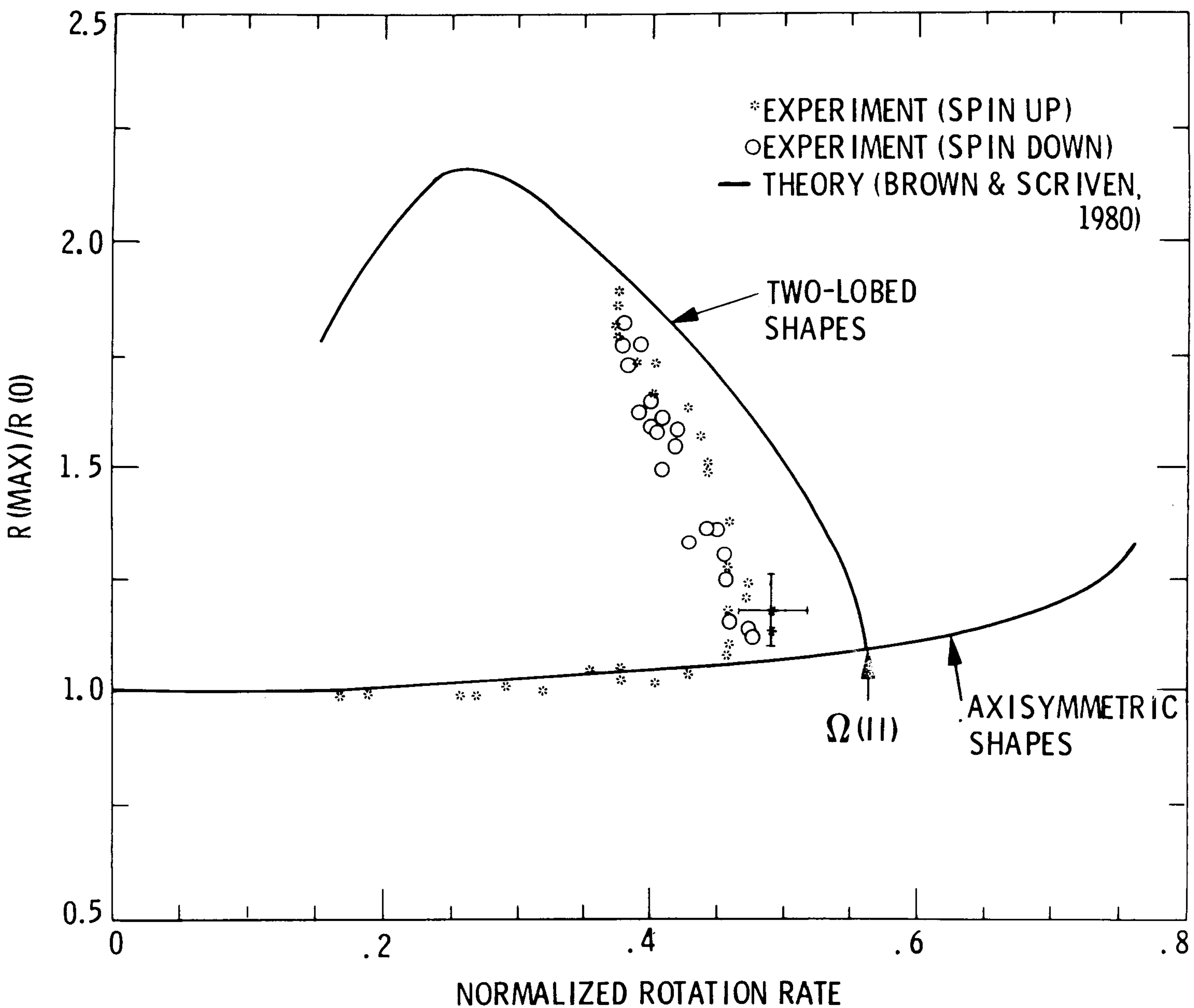

*EXPERIMENT (SPIN UP)
○EXPERIMENT (SPIN DOWN)
— THEORY (BROWN & SCRIVEN, 1980)
TWO-LOBED SHAPES
AXISYMMETRIC SHAPES
Ω(II)
R (MAX)/R (0)
NORMALIZED ROTATION RATE
2.5
2.0
1.5
1.0
0.5
0
.2
.4
.6
.8

Figure 1.

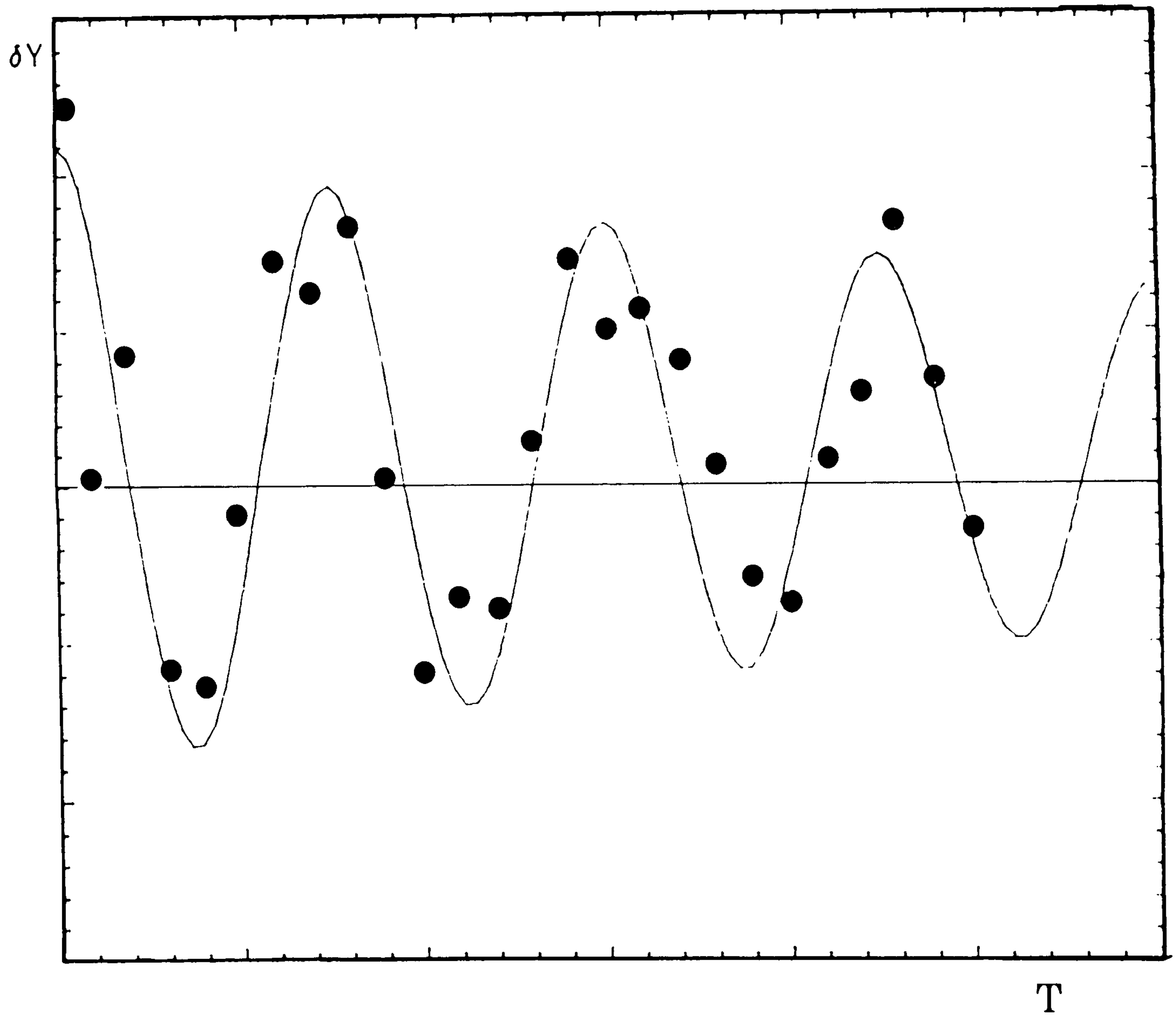

Figure 2. Free decay of an initially deformed drop versus time.